V.F.6 Stationary and Emerging Market Fuel Cell System Cost Analysis—Primary Power and Combined Heat and Power Applications

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Overall Objectives

The objective of this project is to assist DOE in developing fuel cell systems for stationary and emerging markets by developing independent cost models for manufacture and ownership.

- Identify the fundamental drivers of system cost and the sensitivity of the cost to system parameters
- Help DOE prioritize investments in research and development of components (e.g., metal bipolar plates versus composite graphite plates in polymer electrolyte membrane [PEM] fuel cells for low volume markets) to reduce the costs of fuel cell systems while considering systems optimization
- Identify manufacturing processes that must be developed to commercialize fuel cells
- Provide insights into the optimization needed for use of off-the-shelf components in fuel cell systems

Fiscal Year (FY) 2015 Objectives

- Finalize cost estimates of 1 kW, 5 kW, 10 kW, and 25 kW PEM and solid oxide fuel cell (SOFC) [1] systems for primary power and combined heat and power (CHP) applications at annual production volumes of 100, 1,000, 10,000 and 50,000 units
- Initiate cost estimates of 100 kW and 250 kW PEM and SOFC systems for primary power and CHP applications at annual production volumes of 100, 1,000, 10,000, and 50,000 units
- Initiate cost estimates of 5 kW PEM fuel cell systems for backup power applications at annual production volumes of 100, 1,000 and 10,000 units

Technical Barriers

This project addresses the following technical barrier from the Fuel Cells section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(B) Cost

Technical Targets

To widely deploy fuel cells, significant strides must be made in lowering the cost of components and overall systems without compromising reliability and durability. This cost analysis will:

- Identify the fundamental drivers of component and system cost and the sensitivity of the cost to various component and system parameters.
- Provide DOE information on the impact of production volumes on lowering costs of fuel cells and the types of high volume manufacturing processes that must be developed to enable the widespread commercialization.
- Provide insights into the optimization needed for use of off-the-shelf components in fuel cell systems to drive down system costs.
- Analyze the lifecycle costs of owning and operating a fuel cell to estimate primary cost drivers for the end user in applicable markets.

FY 2015 Accomplishments

- Completed manufacturing cost analysis of 1 kW, 5 kW, 10 kW, and 25 kW PEM and SOFC fuel cell systems for primary power and CHP applications
- Completed detailed performance specifications, system requirements, and preliminary system design of 100 kW and 250 kW PEM and SOFC systems for primary power and CHP applications
- Completed detailed performance specifications, system requirements, and preliminary system design of 5 kW PEM fuel cell systems for backup power applications

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INTRODUCTION

Fuel cell power systems may be beneficially used to offset all or a portion of grid-purchased electrical power and supplement on-site heating requirements. For this application, the fuel of choice will usually be pipeline natural gas or on-site propane storage. These fuel sources generally have much higher reliability than utility electric power, being less subject to damage-related outages, and can therefore provide for some continued operation in the event of grid outage—performing both primary power and back-up power functions. Battelle evaluated low temperature polymer electrolyte membrane (LTPEM) and solid oxide fuel cell (SOFC) systems for use as a continuous power supplement (primary power) and to provide auxiliary heating in combined heat and power (CHP) configurations. The power levels considered were 1 kW, 5 kW, 10 kW, and 25 kW. A primary-power/CHP commercial market has not yet developed in this size range; however, our analysis suggests an attractive business opportunity under the right conditions.

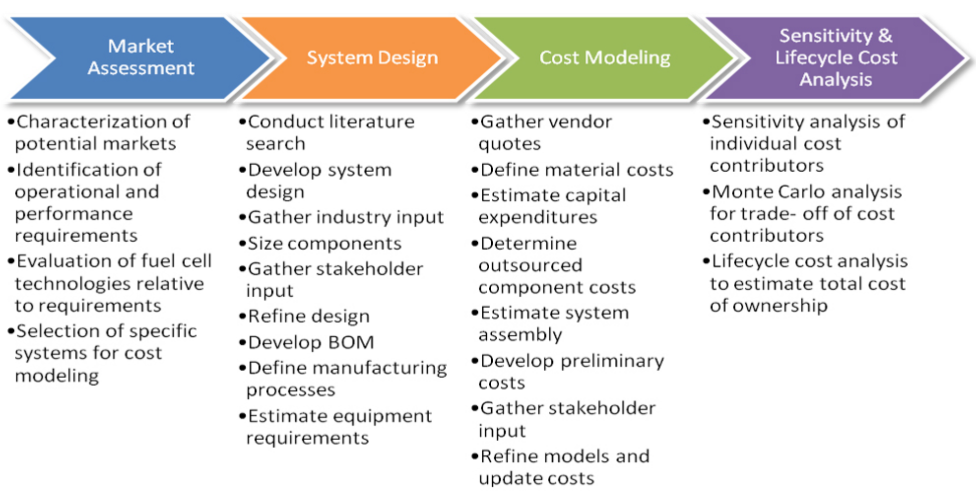
APPROACH

Battelle will apply the established methodology used successfully in previous fuel cell cost analysis studies performed for DOE [1–3]. This technical approach consists of four steps, market assessment, system design, cost modeling, and sensitivity analysis (Figure 1). The first step characterizes the potential market and defines the requirements for system design. The second step involves developing a viable system design and the associated manufacturing process vetted by industry. The third step involves building the cost models and gathering inputs to estimate manufacturing costs. Manufacturing costs will be derived using the Boothroyd-Dewhurst Design for Manufacture Assembly (DFMA®) software. Custom manufacturing process models will be defined where necessary and parametrically modeled based on knowledge of the machine, energy and labor requirements for individual steps that comprise the custom process. The fourth step will evaluate the sensitivity of stack and system costs to various design parameters. In addition to the sensitivity analysis, we will conduct a lifecycle cost analysis to estimate total cost of ownership for the target application and markets.

RESULTS

Overall the final cost was analyzed in four distinct categories, the capital cost of manufacturing equipment, the direct cost of material and assembly of the stack, the expense of balance of plant (BOP) hardware, and the final cost of complete system assembly and testing it. BOP was further broken out into two subsets including CHP hardware and fuel cell system BOP hardware.

A sales markup of 50% was integrated at the end and is called out separately in Tables 1–4. At high production volumes, the final ticket prices are estimated to be \$4,359/kW and \$2,309/kW, respectively, for 5 kW and 25 kW CHP PEM fuel cell systems and \$3,615/kW and \$1,907/kW for the 5 kW and 25 kW CHP SOFC systems. This work provides a detailed cost breakdown that helps identify key cost drivers and offers insight at various value propositions through the lifecycle cost analyses.



BOM – bill of materials

FIGURE 1. Battelle's cost analysis methodology

TABLE 1. 5 kW CHP PEM Fuel Cell System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$32,200	$12,967	$7,329	$5,779
Stack manufacturing capital cost	$481	$76	$54	$48
CHP Hardware	$22,325	$18,705	$17,279	$16,298
FC BOP Hardware	$26,658	$20,780	$17,520	$16,097
System assembly, test, and conditioning	$2,777	$452	$283	$257
Total system cost, pre-markup	$84,442	$52,980	$42,465	$38,480
System cost per net kW, pre-markup	$3,378	$2,119	$1,699	$1,539
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$126,663	$79,471	$63,697	$57,721
System cost per net kW, with markup	$5,067	$3,179	$2,548	$2,309

TABLE 2. 25 kW CHP PEM Fuel Cell System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$6,333	$3,923	$2,446	$2,137
Stack manufacturing capital cost	$295	$47	$65	$56
CHP Hardware	$5,112	$4,456	$4,054	$3,838
FC BOP Hardware	$9,311	$7,093	$6,150	$5,856
System assembly, test, and conditioning	$1,946	$316	$178	$162
Total system cost, pre-markup	$22,998	$15,834	$12,893	$12,050
System cost per net kW, pre-markup	$4,600	$3,167	$2,579	$2,410
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$34,497	$23,751	$19,339	$18,075
System cost per net kW, with markup	$6,899	$4,750	$3,868	$3,615

TABLE 3. 5 kW CHP SOFC System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$16,978	$5,847	$2,835	$2,039
Stack manufacturing capital cost	$481	$62	$24	$24
CHP Hardware	$4,915	$4,293	$3,934	$3,719
FC BOP Hardware	$14,231	$11,042	$9,268	$8,497
System assembly, test, and conditioning	$2,737	$433	$274	$252
Total system cost, pre-markup	$39,343	$21,677	$16,335	$14,531
System cost per net kW, pre-markup	$7,869	$4,335	$3,267	$2,906
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$59,014	$32,515	$24,503	$21,796
System cost per net kW, with markup	$11,803	$6,503	$4,901	$4,359

FC – fuel cell

TABLE 4. 25 kW CHP SOFC System Cost Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$16,075	$9,600	$6,637	$5,930
Stack manufacturing capital cost	$295	$245	$177	$164
CHP Hardware	$23,134	$19,433	$17,939	$16,939
FC BOP Hardware	$14,426	$10,508	$9,097	$8,546
System assembly, test, and conditioning	$2,211	$442	$238	$198
Total system cost, pre-markup	$56,142	$40,228	$34,087	$31,778
System cost per net kW, pre-markup	$2,246	$1,609	$1,363	$1,271
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$84,214	$60,342	$51,131	$47,666
System cost per net kW, with markup	$3,369	$2,414	$2,045	$1,907

CONCLUSIONS AND FUTURE DIRECTIONS

The following lists some of the conclusions drawn from this analysis.

- Electronics and power conversion dominate system cost, particularly as system size increases.
- An attractive value proposition exists under specific utility rate conditions.
- Manufacturing readiness level (MRL) for many BOP components indicates they are not ready for mass production—significant cost driver.
- DFMA® performed on specific components (fuel processing, stack) assumes the technology has an MRL greater than 9.

By the end of FY 2015 Battelle will have completed full cost assessments of 100 kW and 250 kW PEM and SOFC systems for primary power and CHP applications. During FY 2015/2016 Battelle will complete a full cost assessment of 5 kW PEM fuel cell systems for backup power applications.

FY 2015 PUBLICATIONS/PRESENTATIONS

1. V. Contini, F. Eubanks, M. Jansen, P. George, and Mahan Mansouri. June 2015. "Stationary and Emerging Market Fuel Cell System Cost Analysis – Primary Power and Combined Heat and Power Applications." DOE Annual Peer Review. Washington, D.C.

REFERENCES

1. Battelle. 2011. "The High Volume Manufacture Cost Analysis of 5 kW Direct Hydrogen Polymer Electrolyte Membrane (PEM) Fuel Cell for Backup Power Applications." Contract No. DE-FC36GO13110.

2. K. Mahadevan, K. Judd, H. Stone, J. Zewatsky, A. Thomas, H. Mahy, and D. Paul. 2007. "Identification and characterization of near-term direct hydrogen proton exchange membrane fuel cell markets." Contract No. DE-FC36GO13110.

3. H. Stone, K. Mahadevan, K. Judd, H. Stein, V. Contini, J. Myers, J. Sanford, J. Amaya, J. Upton, and D. Paul, 2006. "Economics of Stationary Proton Exchange Membrane Fuel Cells." Contract No. DE-FC36-03GO13110.